WO 00/14294 PCT/FR99/02092

PROCESS FOR VACUUM DEPOSITION ONTO A CURVED SUBSTRATE

The present invention pertains, in a general manner, to the vacuum treatment of any substrate of the type whereby, in conformity with the technique of cathodic atomization that is commonly called "sputtering", deposition is provoked, in overall terms, onto this substrate in a chamber and whereby the deposit comprises a layer of material that derives from a source of a given material by, for example, submitting this source of material, which thus serves as the cathode, to appropriate ionic bombardment in which particles are stripped therefrom and these therefore become deposited on the substrate.

It [the present invention] aims more particularly at the case where the substrate that is to be treated is a curved substrate and even a highly curved substrate as is the case, at least, with certain lenses for spectacles and, in particular, for those of high power.

The term curved substrate is thus to be understood here to mean, in a more general manner, a substrate which, in the manner of a lens for spectacles, comprises a more or less accentuated curvature in at least one transverse plane.

Thus, as is known, it is customary to apply a vacuum treatment to certain lenses of spectacles in order to confer particular properties on them such as, for example, anti-reflection properties.

One of the problems that has to be resolved in this regard is to ensure complete uniformity of the thickness that is desirable in the layer of material that is deposited in this way.

The term thickness is to be understood here and in all that follows to mean the optical thickness of the deposited layer, i.e. the product of the physical thickness of this layer and the refractive index of the material that constitutes it.

In the absence of good uniformity of this thickness, any possible residual reflection constitutes the risk of engendering inopportune iridescence.

Now the thickness of the layer of material that is deposited is inversely proportional to the distance of the lens of the spectacles or, in a more general manner, of the substrate that is to be treated, from the source of the corresponding material.

If, as in this case, the substrate is curved, this distance is greater at its periphery than at its center and the thickness of the deposit that is obtained is thus less at the periphery than at the center.

This difference in thickness can become appreciable if, for practical reasons, the curved substrate is arranged to be at a short distance from the source of material, whereby the difference in the distance from its periphery and from its center to this source of material therefore becomes significant precisely because of its curvature.

In practice, this difference in thickness can currently amount to 20%, depending on the substrates and the chamber that is used.

The subject of the present invention is, in a general manner, an arrangement that permits this difference in thickness to be reduced in a simple way.

More precisely, the subject of the invention is, first of all, a process for the vacuum treatment of any curved substrate of the type whereby deposition is provoked onto this curved substrate, whereby the deposit comprises a layer of material that derives from a given source of material and whereby this process is characterized, in a general manner, by the feature that a mask, which is fixed relative to the curved substrate, is interposed between the curved substrate and the source of the material and at a [certain] distance from the curved substrate; the subject of the invention is also any mask that is suitable for use in such a process.

In fact, it is already known that, for various reasons, use can be made of a mask during the vacuum treatment of a curved substrate as is the case, for example, in American patent No. 5,225,057.

However, the curved substrate that is to be treated in this American patent No. 5,225,057 is kept rotating about itself in such a way that the mask is not fixed relative to it.

In addition, this mask is used solely to limit the aperture angle of the beam, by means of which the deposit, which is sought, is produced, without its providing any influence on the same thickness of the layer of material that is obtained at the end of the deposition process.

In fact, it is also known, particularly from American patent No. 5,389,397, that use can be made of a mask that is fixed relative to the substrate during the vacuum treatment of this substrate.

However, the substrates that are to be treated in this American patent No. 5,389,397 are flat.

Having regard to the particular features of the deposition process that come into play when the substrate is a curved substrate, it was impossible to imagine, a priori, that a fixed mask could also be suitable for such a curved substrate.

In addition, the mask that is used in this American patent No. 5,389,397 is [uniformly] filled.

It has now been found, in a rather surprising manner, that significant results are obtained with the mask in accordance with the invention if this mask comprises an annular part.

Without there being any certainty in this connection, it can be imagined, for example, that at the working pressures that are used, which are generally greater than 0.1 Pa and whereby the mean free path of the depositing particles that are at work is of the order of several millimeters, these depositing particles are subject to multiple reflections with the atoms of the plasma-forming gas and that, because of these multiple reflections and also because of the configuration of the chamber that is used, a flux of particles is normally created that is greater in the direction of the center of the substrate than in the direction of its periphery and that, with the interposition of the mask in accordance with the invention

and, more particularly, a mask comprising an annular part, between the source of material and the substrate, this flux of particles is probably less directional, whereby this flux is then at least partially restricted at the center of the substrate where, in the absence of such a mask, a surplus of deposited material is usually observed.

Be that as it may, it is observed and experiments confirm that with a mask having, in accordance with the invention, an annular part, the difference in thickness, which is recorded for the deposit that is obtained, between the periphery of the curved substrate and the center thereof can advantageously be reduced to at least [the order of] 15% or even to at least [the order of] 10%, instead of being of the order of 20%, with the other conditions being the same in other respects.

Still more satisfactory results can be observed if, in accordance with a [further] development of the invention, the mask that is used comprises, in the interior of its annular part, at least one cross piece that connects one to the other of the two zones of this annular part, e.g. along a diameter thereof, together optionally - in this case in accordance with a supplementary development of the invention - with an arm at the exterior of the annular part at each of the extremities of such a cross piece, whereby the arm extends radially relative to the annular part and in the [direction of the] prolongation of this cross piece.

In such a case, the difference in thickness that is observed between the periphery of the curved substrate that is to be treated and the center thereof can advantageously be reduced by at least 5% with other conditions being the same in other respects.

In all these cases, the results that are obtained with a mask in accordance with the invention are all the more surprising since, in practice, this mask can advantageously have a relatively reduced extension, [i.e.] relative to the curved substrate that is to be treated, whereby this, if desired, permits one to restrict the congestion of the set-up to that of solely the curved substrate and, as a corollary, this permits one to avoid any possible difficulties due to shadow formation.

In particular, particularly favorable results can be obtained with a mask for which the projection onto a plane in accordance with a direction that is perpendicular to this plane has a surface area of less than 10% or even 5% of the surface area of the projection of the curved substrate onto this same plane.

The characteristics and advantages of the invention are also evident from the description that will follow, by way of example, with reference being made to the schematic drawings that are attached in which:

Figure 1 is a perspective view of a curved substrate that is to be treated, illustrated in position on a support with the mask that is associated therewith in accordance with the invention;

Figure 2 is an axial sectional view of the set-up in accordance with the line II-II of Figure 1;

Figure 3 repeats Figure 1, though on a different scale, and is a perspective view of the mask in accordance with the invention that is illustrated in isolation;

Figure 4 is a partially axial sectional view of this mask on a larger scale in accordance with the line IV-IV of Figure 4;

Figure 5 is a partial perspective view that is analogous to that of Figure 3 for a variant embodiment;

Figure 6 is also a perspective view that is analogous to that of Figure 3 for another variant embodiment;

Figure 7 is a partially axial sectional view on a larger scale of this other variant embodiment in accordance with the line VII-VII of Figure 6;

Figures 8, 9 and 10 are perspective views which, analogously to that of Figure 3, also relate, each respectively, to other variant embodiments of the mask in accordance with the invention.

These figures illustrate, by way of example, the application of the invention to the case where the curved substrate 10, which is to be treated, is a lens of spectacles or, more precisely, a quoit [translator: i.e. a round loop] with a circular contour in which such a lens for spectacles is then confined.

Let D_1 be the diameter of this curved substrate 10 across its contour.

This diameter D_1 is most often between 65 mm and 80 mm.

In the form of use that is illustrated, the curved substrate 10 is concavo-convex by way of example.

If a vacuum treatment has to be applied to it, such a curved substrate 10 is usually supported via its periphery by means of a support 11 that is suitable for its maintenance.

Since this support 11 is well known per se and does not relate as such to the present invention, it will not be described here.

It is also for reasons of simple convenience that it is illustrated in the form of a flat disk with a circular contour in Figures 1 and 2.

In reality, this support 11 can take on very different configurations and it can even be perforated.

Be that as it may, for the vacuum treatment that is being sought, one provokes the deposition of a layer of material, in a manner that is known as such, onto the curved substrate 10 that is supported in this regard by a support 11 in a chamber 12, which is schematically illustrated by interrupted dashes in Figure 2, whereby the layer of material derives from a suitable source of material 13, whereby this source is schematically illustrated by interrupted dashes in this Figure 2.

A machine that is used for this objective is marketed, for example, by APPLIED VISION Ltd. under the trade name PLASMACOAT AR.10 (TM).

This machine is also described in international patent application No. WO-A-92 13114.

By way of example, and as schematically represented by 14 in Figure 2, the source of material 13 is provided with a negative potential in order to form a cathode and, on the one hand, an inert gas, e.g. argon, is introduced into the chamber 12, e.g. via a tube 15, and, on the other hand, an active gas, e.g. oxygen, is introduced, e.g. via a tube 16.

Use is generally made of a gas pressure that is greater than 0.1 Pa.

This gas pressure is preferably between 0.2 Pa and 2 Pa.

As a corollary, the support 11 is most often an individual support, as illustrated, and, together with other supports 11 of the same type, which each support a curved substrate 10 that is to be treated, it is connected - as illustrated schematically by interrupted dashes in Figure 2 - to a collective support 18, e.g. in the form of a plate, that is mounted in a rotary manner in the chamber 12.

As a variant, the support 11 can also pass linearly under the source of material 13.

Be that as it may, the inert gas that is introduced via the tube 15 is ionized upon its entrance into the chamber 12 while forming a type of plasma there and positive ions, which thus bombard the source of material 13 which forms a target, and particles are thus stripped off from this source of material 13 which, while combining with the active gas that is introduced via the tube 16, become deposited onto the curved substrate 10 while forming the layer of material, which is being sought, at the surface thereof.

The preceding arrangements are well known as such and will not therefore be described in more detail here.

In accordance with the invention, a mask 19, which is fixed relative to the curved substrate 10, is interposed between the curved substrate 10 and the source of material 13.

Preferably, and as illustrated, a mask comprising an annular part 20 is selected for the mask 19.

In practice, this annular part 20 has a circular contour.

For example, and as illustrated, a mask whose annular part 20 has an external diameter D_2, which is less than two times the diameter D_1 of the curved substrate 10, is selected for the mask 19.

More precisely, a mask whose annular part 20 has an external diameter D_2, which is between one quarter of the diameter D_1 of the curved substrate 10 and two times this diameter D_1, is preferably selected for the mask 19.

It is also possible to indicate in this connection and by way of a numerical example, though without this being able to result in any limitation whatsoever of the invention, that satisfactory results have been obtained with a mask 19 whose annular part 20 has an external diameter D_2, which is between 20 mm and 130 mm, with a curved substrate 10 whose diameter D_1 is of the order of 65 mm and whose power is 6 diopters and whose front convex face has a radius of 62.13 mm.

Be that as it may and since the curved substrate 10 is supported by a support 11 as indicated above, the mask 19, for example, is fixed to this support 11.

In the form of embodiment that has been illustrated, the mask 19 is, in practice, connected to the support 11 via a bracket and it extends in an overhanging manner relative to the extremity of the cross piece 23 of this bracket 22.

Naturally, one preferably proceeds in such a way that this bracket 22 is as small as possible in order to minimize shadow formation of which it can be the origin during the deposition of material onto the curved substrate 10.

Be that as it may and as illustrated, the mask 19 is preferably arranged at a [certain] distance from the curved substrate 10 and, in essence, parallel thereto.

Let d be this distance as measured between the mask 19 at the base thereof and the highest point of the curved substrate 10 as recorded in Figure 2.

For example, this distance d is less than two times the diameter D_1 of the curved substrate 10.

It is preferably between one tenth of the diameter D_1 of the curved substrate 10 and one half of this diameter D_1.

It is also possible to indicate in this connection and by way of a non-limitative example and under the same conditions as above that satisfactory results have been obtained with a distance d between the mask 19 and the curved substrate 10 that is less than 130 mm and, preferably, between 7 mm and 30 mm.

In the forms of embodiments that are illustrated in Figures 1 to 5, the mask 19 becomes smaller at its annular part 20.

For example and as illustrated, the transverse section of this annular part 20 is, in an overall manner, rectangular.

Let H be its height measured in accordance with the axis of the curved substrate 10 and thus perpendicularly to the support 11 that supports it and let E be its radial thickness measured parallel to this support 11.

It is preferable, and this is the case in the forms of embodiment that are illustrated, that the annular part 20 of the mask 19 has a height H in the transverse section that is greater than its radial thickness E.

For example, this height H is less than 15 mm.

It is preferably between 1 mm and 15 mm.

It is also possible to indicate in this connection and by way of a non-limitative example and under the same conditions as above that satisfactory results have been obtained with a height H that is between 1 mm and 10 mm.

Likewise, satisfactory results have been obtained with a radial thickness E that is less than 2 mm.

For example, this radial thickness E is less than 1 mm.

It is also possible to indicate in this connection and by way of a non-limitative example and under the same conditions as above that satisfactory results have been obtained with a radial thickness E that is of the order of 0.1 mm.

It also appears that, in order to obtain satisfactory results, it is desirable to take account of the diameter D_1 of the curved substrate 10, which is to be treated, during the selection of the diameter D_2 of the annular part 20 of the mask 19 that is used.

In order to do this and in accordance with the invention, one ensures that account is taken of at least one of the following formulas and, preferably, each one of these:

$$d + H = A \cdot D_2/2 \qquad \text{(i)}$$

$$d = B \cdot D_2/2 \qquad \text{(ii)}$$

$$D_1 = C \cdot D_2 \qquad \text{(iii)}$$

in which d, H, D_1 and D_2 are the parameters that have already been specified above and in which:

A is a coefficient that is between 0.8 and 1, being e.g. of the order of 0.92;

B is a coefficient that is between 0.7 and 0.9, being e.g. of the order of 0.77;

and C is a coefficient that is between 2 and 3, being e.g. of the order of 2.5.

In the form of embodiment illustrated in Figure 5, the height H has a value that is double the value that it has in the form of embodiment that is illustrated in Figure 3.

In the forms of embodiment illustrated in Figures 6 to 10, the mask 19 comprises at least one cross-piece 24 in the interior of its annular part 20, whereby this cross piece connects one to the other of the two zones of this annular part 20.

For example, and as illustrated in Figures 6 to 8, a sole cross piece 24 is provided and this cross piece 24 extends along a diameter of the annular part 20.

In these forms of embodiment, moreover, the transverse section of this cross piece 24 is, in an overall way, rectangular and it extends essentially parallel to that of the annular part 20.

In the forms of embodiment that are illustrated in Figures 6 to 8, the cross piece 24 has a height H' in the transverse section that is equal to the height H of the annular part 20 and it has a radial thickness E' that is equal to the radial thickness E of this annular part 20.

It thus extends on a level with the annular part 20 as much from the side of one of the faces thereof as from the side of the other of these faces.

Naturally, however, the cross piece 24 can, as a variant, have a height H' in the transverse section that is different from the height H of the annular part 20 and/or a radial thickness E' that is different from the radial thickness E of this annular part 20.

This is the case, by way of example, at least for the height H' in the forms of embodiments that are illustrated in Figures 9 and 10 in which, in addition, the mask 19 in accordance with the invention comprises at least two cross pieces 24.

For example and as illustrated, only two cross pieces 24 are thus provided and they are perpendicular to one another with each, in practice, extending along a diameter of the annular part 20.

For example, these two cross pieces 24 each have a constitution that is analogous to that of the preceding cross piece 24.

In the forms of embodiment that are illustrated, however, their height H' is equal to one half of the height H of the annular part 20.

For example, and as illustrated, they extend at mid-height over this annular part 20.

In the form of embodiment that is illustrated in Figure 10, finally, the mask 19 comprises at least one arm 25 at the exterior of its annular part 20, whereby this arm extends radially relative to this annular part 20 and in an overhanging manner relative thereto.

In practice, this arm 25 has a structure that is analogous to that of the cross pieces 24 and it extends in the prolongation of such a cross piece 24.

In practice, likewise, there is an arm 25 at each of the extremities of a cross piece 24 and the various arms 25, which are used in this way, have the same length for both of the cross pieces 24.